

REACTOR FOR TREATING GASEOUS POLLUTANTS AND HEAD ASSEMBLY THEREOF

FIELD OF THE INVENTION

The present invention relates to a reactor for treating gaseous pollutants
5 and a head assembly thereof, and more particularly to a reactor for treating
an effluent from a semiconductor process and a head assembly thereof.

BACKGROUND OF THE INVENTION

Effluent generated in semiconductor processes contains various
chemical substances that are harmful to human health or the environment.
10 Common treatment systems include combustion-based, plasma-based, wet
scrubbing, and catalytic systems.

For pollutants such as silane (SiH_4), arsine (AsH_3), and phosphine (PH_3)
generated in chemical vapor deposition (CVD) processes, combustion-type
treatment systems are commonly employed. Conventional commercial
15 products include, for example, the ESCAPE system from DAS
Environmental Expert GmbH and the Spectra series from Edwards. Similar
configurations are also disclosed in, for example, U.S. Pat. Nos. 11,162,676
B2 and 7,985,379 B2.

In typical combustion-type treatment systems, a top-inlet configuration
20 is commonly adopted, and combustion and thermal reactions are performed
at an upper portion of the reactor. As a result, a top cover or an upper outer
wall of the reactor exhibits elevated temperatures, which may pose a safety
risk during operation or maintenance.

SUMMARY OF THE INVENTION

25 A head assembly for a combustion-type reactor for treating gaseous

pollutants is provided. The head assembly comprises a cover assembly, one or more guiding conduits, a pilot flame nozzle, and one or more fuel nozzles. The cover assembly is disposed above a thermal reaction region and includes a top plate, a middle plate, and a bottom plate. A first region
5 configured to receive a cooling fluid is defined between the top plate and the middle plate, and a second region configured to receive a thermal insulation material is defined between the middle plate and the bottom plate. The bottom plate includes a first opening and one or more second openings. The one or more guiding conduits are configured to guide an effluent stream
10 from a semiconductor process, wherein the guiding conduits extend through the top plate, the middle plate, and the bottom plate to guide the effluent stream into the thermal reaction region. The pilot flame nozzle is configured to supply a pilot flame, wherein the pilot flame nozzle extends through the top plate, the thermal insulation material, and the middle plate
15 and communicates with the thermal reaction region through the first opening. The one or more fuel nozzles are configured to supply a fuel, wherein the fuel nozzles extend through the top plate, the thermal insulation material, and the middle plate and communicate with the thermal reaction region through the one or more second openings.

20 In one embodiment, the pilot flame nozzle is disposed at a central portion of the cover assembly and directed downward, and is vertically oriented and aligned with a vertical direction. The fuel nozzle is disposed at an outer annular portion of the cover assembly and directed downward, and is oriented along an inclined direction, wherein the vertical direction
25 intersects the inclined direction, such that a localized high-temperature is

created in a region below a bottom surface of the cover assembly by the pilot flame supplied by the pilot flame nozzle and the fuel supplied by the fuel nozzle.

In one embodiment, the region is spaced from the bottom surface by a
5 distance between 100 mm and 300 mm.

In one embodiment, the fuel nozzle is inclined relative to the pilot flame nozzle at an angle between 5° and 35° .

In one embodiment, the fuel nozzle comprises a first fuel nozzle and a second fuel nozzle. The first fuel nozzle and the second fuel nozzle are
10 respectively disposed at a first side and a second side of the head assembly, the first side and the second side being separated by a horizontal distance, and the first fuel nozzle and the second fuel nozzle are inclined toward a central axis of the head assembly.

A reactor for treating gaseous pollutants is further provided,
15 comprising an inlet module, a reaction module, a combustion module, a cooling module, and a thermal insulation material. The inlet module comprises one or more guiding conduits configured to guide an effluent stream from a semiconductor process. The reaction module is coupled below the inlet module and includes a thermal reaction chamber, a bottom
20 chamber located below the thermal reaction chamber, and a cover assembly disposed at an upper opening of the thermal reaction chamber. The guiding conduits extend substantially vertically through the cover assembly to guide the effluent stream into the thermal reaction chamber. The cover assembly includes a top plate, a middle plate, and a bottom plate. A first region is
25 defined between the top plate and the middle plate, and a second region is

defined between the middle plate and the bottom plate. The bottom plate includes a first opening and one or more second openings. The combustion module comprises a pilot flame nozzle, one or more fuel nozzles, and a porous sleeve. The pilot flame nozzle and the fuel nozzles extend through
5 the top plate and the middle plate of the cover assembly and are exposed in the second region, and are respectively in communication with the first opening and the one or more second openings. The porous sleeve extends downward from the first opening of the bottom plate and allows a pilot flame supplied by the pilot flame nozzle to pass into the thermal reaction
10 chamber to ignite the fuel supplied by the fuel nozzles. The cooling module comprises a cooling fluid source and one or more cooling conduits connected to the cooling fluid source, wherein the cooling conduits are configured to supply cooling water to the first region. The thermal insulation material is disposed in the second region and includes a first through hole
15 corresponding to the first opening and one or more second through holes corresponding to the one or more second openings.

In one embodiment, the pilot flame nozzle is disposed at a central portion of the cover assembly and directed downward, and is vertically oriented and aligned with a vertical direction. The fuel nozzle is disposed at
20 an outer annular portion of the cover assembly and directed downward, and is oriented along an inclined direction, wherein the vertical direction intersects the inclined direction, such that a localized high-temperature is created in a region below a bottom surface of the cover assembly by the pilot flame supplied by the pilot flame nozzle and the fuel supplied by the
25 fuel nozzle.

In one embodiment, the region is spaced from the bottom surface by a distance between 100 mm and 300 mm.

In one embodiment, the fuel nozzle is inclined relative to the pilot flame nozzle at an angle between 5° and 35° .

5 In one embodiment, the fuel nozzle comprises a first fuel nozzle and a second fuel nozzle. The first fuel nozzle and the second fuel nozzle are respectively disposed at a first side and a second side of the head assembly, the first side and the second side being separated by a horizontal distance, and the first fuel nozzle and the second fuel nozzle are inclined toward a
10 central axis of the head assembly.

In one embodiment, the thermal reaction chamber includes an annular gap and a reservoir in fluid communication with the annular gap, wherein the reservoir provides a water curtain that flows downward along an inner wall of the thermal reaction chamber via the annular gap.

15 A reactor for treating gaseous pollutants is further provided, comprising a thermal reactor, one or more guiding conduits, a pilot flame nozzle, and one or more fuel nozzles. The thermal reactor includes a reactor body, an internal region defined by the reactor body, and a partition separating the internal region from an external environment. The partition
20 includes an outer cover plate, a first space disposed within the reactor body and adjacent to the outer cover plate, and a second space disposed separately from the first space. The one or more guiding conduits are configured to guide an effluent stream from a semiconductor process into the internal region of the thermal reactor. The pilot flame nozzle is configured to provide
25 a pilot flame to the internal region of the thermal reactor. The one or more

fuel nozzles are configured to provide a fuel to the internal region of the thermal reactor. The fuel is ignited by the pilot flame such that the effluent stream is burned within the internal region. The first space and the second space respectively accommodate a first medium and a second medium
5 configured to reduce heat transfer, such that a temperature of the partition is lower than that of the internal region.

In one embodiment, the pilot flame nozzle is disposed at a central portion of a top of the thermal reactor and directed downward, and is vertically oriented and aligned with a vertical direction. The fuel nozzle is
10 disposed at an outer annular portion of the top and directed downward, and is oriented along an inclined direction, wherein the vertical direction intersects the inclined direction, such that a localized high-temperature is created in an upper region of the thermal reactor by the pilot flame supplied by the pilot flame nozzle and the fuel supplied by the fuel nozzle.

15 In one embodiment, the fuel nozzle is inclined relative to the pilot flame nozzle at an angle between 5° and 35° .

In one embodiment, the fuel nozzle comprises a first fuel nozzle and a second fuel nozzle. The first fuel nozzle and the second fuel nozzle are respectively disposed at a first end and a second end of the top of the thermal
20 reactor, the second end being separated from the first end by a horizontal distance, and the first fuel nozzle and the second fuel nozzle are inclined toward a central axis of the thermal reactor.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1A is a schematic perspective view of an assembled apparatus
25 according to an embodiment of the present invention.

FIG. 1B is a schematic perspective view of an assembled apparatus according to an embodiment of the present invention.

FIG. 2 is a schematic perspective cross-sectional view of FIG. 1A taken along an XZ plane.

5 FIG. 3A is a schematic cross-sectional view of a thermal reaction and wet scrubbing unit according to an embodiment of the present invention.

FIG. 3B is an enlarged partial view of FIG. 3A.

FIG. 3C is a schematic view illustrating an embodiment of FIG. 3B.

FIGS. 4A and 4B are exploded views of a cover assembly according to an
10 embodiment of the present invention.

FIG. 5 is a schematic cross-sectional view of partial components according to an embodiment of the present invention.

DETAILED DESCRIPTION

The following embodiments are applied to the treatment of an effluent
15 stream from a semiconductor process, such as waste gas. Although the term “water” is used in multiple instances herein, this terminology is solely for convenience of description, and the present invention is not limited thereto, other alternative liquids may be used.

As used herein, the terminology employed in the description of various
20 embodiments is for the purpose of describing particular examples and is not intended to be limiting. Unless the context clearly indicates otherwise, or unless the number of elements is expressly limited, the singular forms “a,” “an,” and “the” may also include plural forms. In addition, the terms “comprising” and “including” are intended to be inclusive, indicating that
25 additional elements beyond those listed may be present. When an element

is described as being “connected” or “coupled” to another element, the element may be directly connected or coupled to the other element, or may be connected or coupled to the other element through an intermediate element. When a layer, region, or substrate is described as being “on”
5 another element, it may be directly on the other element or may have an intermediate element therebetween. In contrast, when an element is described as being “directly on” another element, no such intermediate element is present. In addition, the order of description of the embodiments should not be construed as implying that operations or steps must follow the
10 literal order described, and alternative embodiments may perform steps, operations, or methods in an order different from that described herein.

An aspect of the present invention discloses a combustion-type waste gas treatment apparatus (may also be referred to as a thermal oxidation waste gas treatment apparatus). In one example, the waste gas treatment
15 apparatus is a combustion wet-type waste gas treatment apparatus. Referring to FIGS. 1A, 1B, and 2, FIGS. 1A and 1B are schematic perspective views of an assembled apparatus according to an embodiment of the present invention, and FIG. 2 is a cross-sectional perspective view of FIG. 1A taken along an XZ plane. In the present embodiment, the waste gas
20 treatment apparatus includes a thermal reaction and wet scrubbing unit 10, a water tank unit 20, a secondary wet scrubbing unit 30, a filter unit, and a demisting unit. The waste gas treatment apparatus may be controlled by a control unit.

The thermal reaction and wet scrubbing unit 10 and the secondary wet
25 scrubbing unit 30 are respectively disposed above the water tank unit 20.

The filter unit is connected to the secondary wet scrubbing unit 30 and is located above the secondary wet scrubbing unit 30. The demisting unit is connected to the filter unit and is located above the filter unit. In other words, the secondary wet scrubbing unit 30, the filter unit, and the demisting unit are sequentially located downstream of the thermal reaction and wet scrubbing unit 10.

The thermal reaction and wet scrubbing unit 10 may be connected downstream of a semiconductor processing apparatus. The thermal reaction and wet scrubbing unit 10 includes an inlet module 11, a combustion module 12, a reactor module 13, a cooling module 14, and a spraying module 15. In some examples, the thermal reaction and wet scrubbing unit 10 may also be connected downstream of, but not limited to, solar cell processing equipment or display panel processing equipment, and receives an effluent stream from such equipment.

The inlet module 11 includes a plurality of guiding conduits 110. In this example, the number of the guiding conduits 110 is four, and the guiding conduits 110 receive an effluent stream from the semiconductor processing apparatus. The combustion module 12 includes a pilot flame assembly 121 and a plurality of burner assemblies 122. As shown in FIG. 2, the pilot flame assembly 121 includes a tube 1211, a pilot flame nozzle 1212, and a spark plug. The pilot flame nozzle 1212 is configured to supply a pilot flame and communicate with the reactor module 13. Each burner assembly 122 includes a first conduit 1221, a second conduit 1222, a third conduit 1223, a fuel nozzle 1224, and a premixing chamber 1225. The first conduit 1221 and the second conduit 1222 deliver fuel to the premixing chamber 1225,

and the fuel is conveyed through the third conduit 1223 and discharged from the fuel nozzle 1224 to the reactor module 13. The first conduit 1221 is used to deliver an oxidant to the premixing chamber 1225. The oxidant may be, for example, oxygen, ozone, air, compressed dry air (CDA), oxygen-enriched air, or a combination thereof. The second conduit 1222 is used to deliver a fuel gas to the premixing chamber 1225. The fuel gas may be, for example, hydrogen, methane, natural gas, propane, liquefied petroleum gas (LPG), or a combination thereof. The oxidant and the fuel gas are mixed in the premixing chamber 1225 to form a mixed fuel, and the spark plug is used to provide a pilot flame. The pilot flame is ejected downward through the tube 1211 and the pilot flame nozzle 1212. The mixed fuel is transmitted through the inclined third conduit 1223 and is ejected from the fuel nozzle 1224 toward a region below the fuel nozzle 1224 and obliquely toward the pilot flame, such that a combustion flame is generated near the pilot flame nozzle 1212 of the pilot flame assembly 121.

Referring to FIGS. 3A, 3B, 3C, 4A, and 4B, the reactor module 13 is a thermal reactor and is coupled downstream of the inlet module 11, and in this example is located below. The reactor module 13 includes a reactor body 131 and a cover assembly 132. The reactor body 131 may be in a cylindrical or conical shape and defines a thermal reaction chamber 131a, an upper opening 131b located above the thermal reaction chamber 131a, and a bottom chamber 131c located below the thermal reaction chamber 131a.

The cover assembly 132 is disposed at the upper opening 131b. As shown in FIGS. 4A and 4B, the cover assembly 132 includes a top plate

1321, a middle plate 1322, and a bottom plate 1323, which are stacked. In this example, a bottom surface 1321e of the top plate 1321 is planar, and the middle plate 1322 has a recessed structure 1322d, such that a first region 132a is provided between the top plate 1321 and the middle plate 1322. The first region 132a is a first space extending along an XY plane. A bottom surface 1322e of the middle plate 1322 has a recessed structure, and the bottom plate 1323 has a recessed structure 1323d, such that a second region 132b is provided between the middle plate 1322 and the bottom plate 1323. The second region 132b is a second space extending along the XY plane.

10 The first region 132a is configured to receive a cooling fluid, and the second region 132b is configured to receive a thermal insulation material. A first annular wall 1324 is disposed between the middle plate 1322 and the top plate 1321. The middle plate 1322, the top plate 1321, and the first annular wall 1324 define the first region 132a. A second annular wall 1325 is

15 disposed between the middle plate 1322 and the bottom plate 1323, and the middle plate 1322, the bottom plate 1323, and the second annular wall 1325 define the second region 132b.

Referring again to FIGS. 4A and 4B, the top plate 1321 has a first opening 1321a, a plurality of second openings 1321b, and a plurality of third openings 1321c. The middle plate 1322 has a first opening 1322a, a plurality of second openings 1322b, and a plurality of third openings 1322c. The bottom plate 1323 has a first opening 1323a, a plurality of second openings 1323b, and a plurality of third openings 1323c. The first openings 1321a, 1322a, and 1323a correspond to each other in a vertical direction.

25 The second openings 1321b, 1322b, and 1323b correspond to each other in

a vertical direction. The third openings 1321c, 1322c, and 1323c correspond to each other in a vertical direction.

The tube 1211 of the pilot flame assembly 121 is inserted into the first openings 1321a and 1322a and the pilot flame nozzle 1212 is exposed
5 above the first opening 1323a. The third conduit 1223 of the burner assembly 122 is inserted into the second openings 1321b and 1322b and the fuel nozzle 1224 is exposed above the second opening 1323b. The guiding conduits 110 are inserted into the third openings 1321c, 1322c, and 1323c and gas outlets are exposed in the thermal reaction chamber 131a. In this
10 example, when viewed from above, the tube 1211 of the pilot flame assembly 121 is located at a center of the cover assembly 132. Two burner assemblies 122 are provided, and the third conduits 1223 thereof are located at opposite sides along a transverse axis (e.g., an X-axis). Six of the guiding conduits 110 are provided. In this embodiment, for clarity of illustration,
15 certain conduits are omitted from the drawings to clearly show the interconnection among the components disclosed herein. The guiding conduits 110 are arranged around the center on the cover assembly 132.

The tube 1211 of the pilot flame assembly 121 and the guiding conduits 110 of the inlet module 11 are vertically arranged. That is, their longitudinal
20 axes are parallel to the longitudinal axis of the reactor body 131. The third conduit 1223 of the burner assembly 122 is arranged in an inclined manner, such that its longitudinal axis intersects the longitudinal axis of the reactor body 131 at an angle. In one example, the angle is between 5° and 35° , such that the fuel provided by the fuel nozzle 1224 can be ignited by the pilot
25 flame to generate burner flames, whereby the thermal reaction chamber

131a serves as a thermal reaction region having a temperature between 500°C and 2000°C, thereby decomposing the effluent stream. In one example, the temperature of the thermal reaction region is between 900°C and 1300°C.

5 Referring in detail to FIG. 3C, the pilot flame nozzle 1212 is disposed downward at a central portion 132c of the cover assembly 132 (as shown in FIGS. 4A and 4B), and the pilot flame nozzle 1212 is vertically aligned along a vertical direction V. The fuel nozzles 1224 are disposed downward at an outer annular portion 132d of the cover assembly 132 (as shown in
10 FIGS. 4A and 4B), and the fuel nozzles 1224 are respectively oriented obliquely along inclined directions S1 and S2. The vertical direction V intersects the inclined directions S1 and S2. Further, the fuel nozzles 1224 include a first fuel nozzle 1224a and a second fuel nozzle 1224b. The first fuel nozzle 1224a and the second fuel nozzle 1224b are respectively
15 arranged at a first end and a second end of the cover assembly 132 along a transverse direction, the second end being spaced apart from the first end by a horizontal distance. The first fuel nozzle 1224a and the second fuel nozzle 1224b are inclined toward a central axis of the cover assembly 132 (the first fuel nozzle 1224a is arranged along the inclined direction S1, and the
20 second fuel nozzle 1224b is arranged along the inclined direction S2).

In this embodiment, the fuel nozzle 1224 is inclined relative to the pilot flame nozzle 1212 at an angle between 5° and 35°. In other words, the vertical direction V intersects the inclined direction S1 at an angle θ_1 , and the vertical direction V intersects the inclined direction S2 at an angle θ_2 .
25 The angle θ_1 and the angle θ_2 are between 5° and 35°, preferably about 20°.

The pilot flame from the pilot flame nozzle 1212 and the mixed fuel from the fuel nozzle 1224 thereby generate a concentrated high-temperature combustion in a region A below a bottom surface of the cover assembly 132. The region A is spaced apart from the bottom surface by a distance D, and the distance D may be between 100 mm and 300 mm. In one example, the angle θ_1 and the angle θ_2 may be the same or different. The cooling module 14 includes a cooling fluid source and one or more cooling conduits 141 connected to the cooling fluid source. The cooling conduits 141 are transversely inserted through the first annular wall 1324 between the middle plate 1322 and the top plate 1321, and supply a cooling fluid, such as cooling water, to the first region 132a. The cooling water may circulate through a circulation conduit to form circulating cooling water. A thermal insulating material is disposed in the second region 132b between the middle plate 1322 and the bottom plate 1323. The thermal insulating material may have a plurality of through holes, through which the guide conduits 110 pass, and which allow the pilot flame nozzle 1212 to communicate with a porous sleeve, and the fuel nozzle 1224 to communicate with the thermal reaction chamber 131a. In one example, the thermal insulating material includes a first through hole corresponding to the first openings 1321a, 1322a, 1323a, one or more second through holes corresponding to the second openings 1321b, 1322b, 1323b, and one or more third through holes corresponding to the third openings 1321c, 1322c, 1323c. The porous sleeve extends downward from the first opening 1323a of the bottom plate 1323 and allows the pilot flame supplied by the pilot flame nozzle 1212 to pass into the thermal reaction chamber 131a to ignite

the fuel supplied by the fuel nozzle 1224.

By means of the dual-layer cooling design of the cover assembly 132 (including the cooling fluid in the first region 132a and the thermal insulation material in the second region 132b), the temperature near the top plate 1321 can be maintained significantly lower than the temperature in the thermal reaction chamber 131a in which combustion occurs, thereby reducing operational risks to personnel. In addition, since the second region 132b adjacent to the thermal reaction chamber 131a is provided with the thermal insulation material, the thermal reaction within the thermal reaction chamber 131a is not adversely affected, including combustion of the fuel and the high temperature therein. On the other hand, the first region 132a adjacent to the exterior contains flowing cooling water, which effectively removes heat. In one embodiment, when cooling water having a temperature between 16°C and 20°C (for example, 18°C) is used, even when the temperature of the thermal reaction chamber 131a exceeds 900°C, the temperature near the top plate 1321 can be maintained below 200°C, thereby significantly improving safety for operators and the operating environment. In contrast, in a combustion-type effluent treatment apparatus without the cooling module 14 and the cover assembly 132, when the temperature of the thermal reaction chamber 131a exceeds 900°C, the external surface temperature is correspondingly elevated, exposing operators to hazardous conditions. In one example, the temperature of the thermal reaction chamber 131a ranges from 900°C to 1300°C, while the temperature near the top plate 1321 is below 200°C.

In one example, the reactor body 131 defines an internal region (i.e.,

the thermal reaction chamber 131a), and the cover assembly 132 serves as a partition separating the internal region from the exterior. The cover assembly 132 (i.e., the partition) includes an outer cover plate, a first space disposed within the reactor body 131 and adjacent to the outer cover plate
5 (i.e., the first region 132a), and a second space (i.e., the second region 132b) disposed apart from the first space. The fuel is ignited by the pilot flame such that the effluent stream is combusted within the internal region. The first space and the second space are respectively provided with a first medium (such as the cooling fluid) and a second medium (such as the
10 thermal insulation material) for reducing heat transfer, such that the temperature of the partition is significantly lower than that of the internal region.

A lateral annular gap 1312 is provided between the upper opening 131b of the reactor body 131 and the cover assembly 132. An outer casing of the
15 reactor body 131 is provided with a water reservoir 134. The water reservoir 134 is connected to an annular flange, and the annular flange includes a plurality of conduits connected to a water source via a plurality of pipelines, thereby supplying water to the water reservoir 134. A stream of water from the water reservoir 134 passes through the annular gap 1312 into the thermal
20 reaction chamber 131a and flows downward along an inner wall 1311a thereof to form a water curtain, thereby washing the effluent stream entering the thermal reaction chamber 131a and cleaning dust, particles, or contaminants adhering to the inner wall 1311a.

The spray module 15 includes a plurality of spray nozzles 151. In a side
25 view, the spray nozzles 151 are arranged obliquely and downward in the

bottom chamber 131c. In a top view, the spray nozzles 151 are oriented non-radially and are offset in a same direction, thereby providing an improved spraying effect. The spray nozzles 151 may dispense an effluent treating agent. The effluent treating agent may be water or water mixed with
5 corrosive agents, acidic agents, ionic or non-ionic surfactants, or coagulants. The spray nozzles 151 may deliver the effluent treating agent in the form of a liquid stream or a mist, and the effluent treating agent is capable of capturing harmful gases or particles in the effluent.

Referring also to FIGS. 2 and 5, FIG. 5 omits illustration of the thermal
10 reaction and wet scrubbing unit 10. The reactor body 131 communicates with the water tank unit 20 via the bottom chamber 131c. The water tank unit 20 includes a water-filled space 21, a partition member 22, a first upper opening 23a, and a second upper opening 23b. The partition member 22 is disposed in the water-filled space 21 and divides the water-filled space 21
15 into a first region 21a and a second region 21b, wherein the first region 21a and the second region 21b are in communication with each other. Water is held in the water-filled space 21 and circulates therein. A water level of the water is lower than a top portion 24 of the water tank unit 20 and higher than the partition member 22, such that lateral flow passages are provided
20 in the first region 21a and the second region 21b to allow the effluent stream to flow laterally therethrough.

The first upper opening 23a and the second upper opening 23b communicate with the first region 21a. The first upper opening 23a communicates with the thermal reaction and wet scrubbing unit 10, and the

second upper opening 23b communicates with the secondary wet scrubbing unit 30. The water tank unit 20 further includes a suction port 26 and a water inlet 27 (as shown in FIG. 1A). The suction port 26 is coupled to a pump line, and the water inlet 27 is used to supply water, which may be fresh
5 make-up water or recirculating water.

The secondary wet scrubbing unit 30 may be a packed bed scrubber. The secondary wet scrubbing unit 30 includes a lower opening 31, one or more compartments 32, one or more spray heads 33, and an upper opening 34. The lower opening 31 is connected to the second upper opening 23b,
10 and the upper opening 34 is connected to the filter unit. The compartments 32 are configured to hold a packing material. The packing material may be selected to have a high surface-to-volume ratio. For example, the packing material may be made of polyvinyl chloride (PVC), but is not limited thereto. The spray heads 33 spray the effluent treating agent onto the
15 packing material, thereby increasing a contact area between the gas or particles in the gas and the effluent treating agent on the packing material, while wetting and rinsing the packing material to capture particles.

The filter unit is connected to the upper opening 34 of the secondary wet scrubbing unit 30. The filter unit includes one or more filters and one or
20 more spray heads. The filters are configured to intercept and remove particles or fine dust in the effluent, such as PM2.5. The spray heads may spray the effluent treating agent to increase capture efficiency and to clean the filters.

The demisting unit is disposed above the filter unit. In one example,

the demisting unit includes one or more condensation plates (not shown). After the preceding water scrubbing processes, the effluent stream contains a certain amount of moisture. To meet emission standards, the effluent stream entering the demisting unit flows through passages partitioned by the condensation plates to increase residence time and contact the condensation plates, such that moisture is separated on the condensation plates. Accordingly, moisture in the effluent stream can be effectively removed after passing through the demisting unit to meet emission standards.

What is claimed is:

1. A head assembly configured to be installed on a combustion-type reactor for treating gaseous pollutants, comprising:
a cover assembly disposed above a thermal reaction region, the cover
5 assembly comprising a top plate, a middle plate, and a bottom plate, wherein a first region configured to receive a cooling fluid is defined between the top plate and the middle plate, and a second region configured to receive a thermal insulation material is defined between the middle plate and the bottom plate, and the bottom plate comprises
10 a first opening and one or more second openings;
one or more guiding conduits configured to guide an effluent stream from a semiconductor process, wherein the guiding conduits extend through the top plate, the middle plate, and the bottom plate to guide the effluent stream into the thermal reaction region;
15 a pilot flame nozzle configured to supply a pilot flame, wherein the pilot flame nozzle extends through the top plate, the thermal insulation material, and the middle plate and communicates with the thermal reaction region through the first opening; and
one or more fuel nozzles configured to supply a fuel, wherein the fuel
20 nozzles extend through the top plate, the thermal insulation material, and the middle plate and communicate with the thermal reaction region through the one or more second openings.
2. The head assembly of claim 1, wherein the pilot flame nozzle is disposed at a central portion of the cover assembly and directed downward, and is
25 vertically oriented and aligned with a vertical direction, and the fuel nozzle

is disposed at an outer annular portion of the cover assembly and directed downward, and is oriented along an inclined direction,

wherein the vertical direction intersects the inclined direction, such that a localized high-temperature is created in a region below a bottom surface of the cover assembly by the pilot flame supplied by the pilot flame nozzle and the fuel supplied by the fuel nozzle.

3. The head assembly of claim 2, wherein the region is spaced from the bottom surface by a distance between 100 mm and 300 mm.

4. The head assembly of claim 2, wherein the fuel nozzle is inclined relative to the pilot flame nozzle at an angle between 5° and 35°.

5. The head assembly of claim 2, wherein the fuel nozzle comprises a first fuel nozzle and a second fuel nozzle, and the first fuel nozzle and the second fuel nozzle are respectively disposed at a first side and a second side of the head assembly, the first side and the second side being separated by a horizontal distance, and the first fuel nozzle and the second fuel nozzle are inclined toward a central axis of the head assembly.

6. A reactor for treating gaseous pollutants, comprising:

an inlet module comprising one or more guiding conduits configured to guide an effluent stream from a semiconductor process;

a reactor module coupled below the inlet module, the reactor module comprising a thermal reaction chamber, a bottom chamber located below the thermal reaction chamber, and a cover assembly disposed at an upper opening of the thermal reaction chamber, wherein the guiding conduits extend substantially vertically through the cover assembly to guide the effluent stream into the thermal reaction chamber, and the

- cover assembly comprises a top plate, a middle plate, and a bottom plate, wherein a first region is defined between the top plate and the middle plate, and a second region is defined between the middle plate and the bottom plate, and the bottom plate comprises a first opening and one or more second openings;
- 5 a combustion module comprising a pilot flame nozzle, one or more fuel nozzles, and a porous sleeve, wherein the pilot flame nozzle and the fuel nozzles extend through the top plate and the middle plate of the cover assembly and are exposed in the second region and respectively
- 10 communicate with the first opening and the second openings, and the porous sleeve extends downward from the first opening of the bottom plate and allows a pilot flame provided by the pilot flame nozzle to pass into the thermal reaction chamber to ignite the fuel;
- a cooling module comprising a cooling fluid source and one or more
- 15 cooling conduits connected to the cooling fluid source, wherein the cooling conduits supply cooling water to the first region; and
- a thermal insulation material disposed in the second region, wherein the thermal insulation material comprises a first through hole corresponding to the first opening and one or more second through
- 20 holes corresponding to the one or more second openings.
7. The reactor of claim 6, wherein the pilot flame nozzle is disposed at a central portion of the cover assembly and directed downward, and is vertically oriented and aligned with a vertical direction, and the fuel nozzle is disposed at an outer annular portion of the cover assembly and directed
- 25 downward, and is oriented along an inclined direction,

wherein the vertical direction intersects the inclined direction, such that a localized high-temperature is created in a region below a bottom surface of the cover assembly by the pilot flame supplied by the pilot flame nozzle and the fuel supplied by the fuel nozzle.

- 5 8. The reactor of claim 7, wherein the region is spaced from the bottom surface by a distance between 100 mm and 300 mm.
9. The reactor of claim 7, wherein the fuel nozzle is inclined relative to the pilot flame nozzle at an angle between 5° and 35°.
10. The reactor of claim 7, wherein the fuel nozzle comprises a first fuel
10 nozzle and a second fuel nozzle, and the first fuel nozzle and the second fuel nozzle are respectively disposed at a first side and a second side of the cover assembly, the first side and the second side being separated by a horizontal distance, and the first fuel nozzle and the second fuel nozzle are inclined toward a central axis of the cover assembly.
- 15 11. The reactor of claim 6, wherein the thermal reaction chamber comprises an annular gap and a water reservoir communicating with the annular gap, wherein the water reservoir provides a water stream flowing downward along an inner wall of the thermal reaction chamber to form a water curtain.
12. A reactor for treating gaseous pollutants, comprising:
20 a thermal reactor including a reactor body, an internal region defined by the reactor body, and a partition separating the internal region from an exterior, wherein the partition comprises an outer cover plate, a first space disposed within the reactor body and adjacent to the outer cover plate, and a second space spaced apart from the first space;

one or more guiding conduits configured to guide an effluent stream into
the internal region;

a pilot flame nozzle configured to supply a pilot flame to the internal region;
and

- 5 one or more fuel nozzles configured to supply a fuel to the internal region;
wherein the fuel is ignited by the pilot flame such that the effluent stream is
burned in the internal region, and the first space and the second space
respectively receive a first medium and a second medium for reducing
heat transfer such that a temperature of the partition is lower than that
10 of the internal region.

13. The reactor of claim 12, wherein the pilot flame nozzle is disposed at a
central portion of a top of the thermal reactor and directed downward, and
is vertically oriented and aligned with a vertical direction, and the fuel
nozzle is disposed at an outer annular portion of the cover assembly and
15 directed downward, and is oriented along an inclined direction,
wherein the vertical direction intersects the inclined direction, such that a
localized high-temperature is created in an upper region of the thermal
reactor by the pilot flame supplied by the pilot flame nozzle and the
fuel supplied by the fuel nozzle.

- 20 14. The reactor of claim 13, wherein the fuel nozzle is inclined relative to
the pilot flame nozzle at an angle between 5° and 35° .

15. The reactor of claim 13, wherein the fuel nozzle comprises a first fuel
nozzle and a second fuel nozzle, and the first fuel nozzle and the second fuel
nozzle are respectively disposed at a first side and a second side of the top,
25 the first side and the second side being separated by a horizontal distance,

and the first fuel nozzle and the second fuel nozzle are inclined toward a central axis of the thermal reactor.